

Developing Tools for Improved Watershed Model Calibration

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Abstract

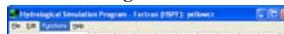
Planning plans to remediate watersheds requires a sophisticated understanding of the degree to which multiple sources contribute contamination. Also of critical importance is an understanding of the relationship between contaminant loads and downstream impacts. Development of a watershed model can be an effective way to conceptualize the problem, hypothesize source/receptor relationships, and evaluate the relative effectiveness of alternative management solutions.

The Hydrologic Simulation Program Fortran (HSPF) is a watershed model that is sufficiently detailed to describe water bodies and will meet water quality standards both before and after remediation. HSPF allows the user to simulate the fate and transport of a number of pollutants and physical types in the watershed environment. The WinHSPF implementation of the HSPF model, a component of the U.S. EPA's Better Assessment Science Integrating point and Nonpoint Sources (BASINS) modeling system, facilitates use of this complex model. BASINS and the WinHSPF system support the population of model input parameters from national Geographic Information System (GIS) coverages and default parameters. In order to accurately describe the fate and transport of contaminants in a watershed, HSPF must be calibrated to minimize the mismatch between model output and monitoring data. While model setup has been greatly facilitated with the development of BASINS and WinHSPF, calibration represents a remaining significant bottleneck in the modeling process.

The Geological Survey (USGS) previously developed a tool to facilitate calibration of HSPF, the PEST Expert System (HSPPEXP). More recently, Watermark Numerical Computing developed a tool for parameter estimation (PEST). Both the U.S. EPA Office of Water (OW) and Office of Research and Development (ORD) had direct experience in applying this next-generation tool and saw its potential for not only speeding model calibration, but for better understanding and describing model uncertainty. The U.S. EPA OW organized a workgroup, including Aqua Terra Consultants (under contract to the OW), the USGS (both with long track records with calibrating HSPF), and Watermark Numerical Computing, who brought to the table a substantial piece of software that was just recently made public domain.

released the PEST feature in WinHSPF with the release of BASINS 3.1. This new feature will help speed the development of model applications and thus make detailed assessments more affordable, along with improved quality and accuracy of these assessments. As model users become more accustomed to automated calibration techniques, they will better understand the strengths and limits of their calibrated models and thus be able to provide better information of model predictive uncertainty to decision-makers.

Calibrating WinHSPF Watershed Model Hydrology with PEST



User simply specifies historic stream flow time series to compare against modeled stream flow

Parameter ESTimation (PEST) Function

PEST Surface Water Utilities

Parameter to Parameter (PAR2PAR)

Calculates monthly varying parameters from user-defined super-parameters; converts transformed parameters back to model-space



Time Series Processor (TSPROC)

Interpolates model output to match observations; calculates flow volumes and flow exceedances

WinHSPF configures PEST to optimize the following hydrology input parameters

Name	Definition
LZSN	moisture storage capacity in the lower soil zone
INFILT	infiltration capacity index
AGWRC	groundwater recession rate
DEEPR	fraction of groundwater lost to deep groundwater
BASETP	baseflow evapotranspiration
AGWEPT	active groundwater evapotranspiration
CEPSC	interception storage capacity
UZSN	moisture storage capacity in the upper soil zone
INTFW	interflow/surface runoff partitioning
IRC	interflow recession rate

PEST iteratively improves the parameter set to reach the best-fit solution

How PEST Calibrates the Model

- Uses a Gauss-Marquardt-Levenberg algorithm to optimize parameter values by minimizing a user-defined objective function
- Iteratively calculates parameter upgrades using a first order Taylor-expansion to linearize model output as function of input parameter values
- Numerically calculates partial derivatives of the Taylor expansion by re-running the model with incremental changes to parameter values
- Minimizes a user-defined objective function that quantifies the misfit between model output and field observations

$$\Phi = \sum_{i=1}^{m_1} (w_{1i} \cdot r_{1i})^2 + \sum_{i=1}^{m_2} (w_{2i} \cdot r_{2i})^2 + \sum_{i=1}^{m_3} (w_{3i} \cdot r_{3i})^2$$

ϕ = objective function value, to be minimized

m_1 = number of observations for component 1

r_{1i} = residual (modeled – observed) for i^{th} observation of component 1

w_{1i} = observation weight for i^{th} observation of component 1

WinHSPF Configures PEST with Three Objective Function Components:

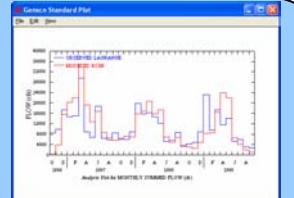
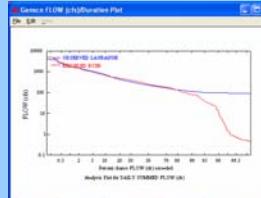
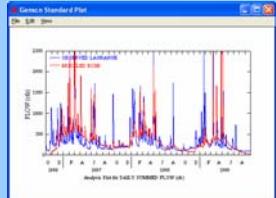
1. Daily Streamflow

2. Flow Exceedances

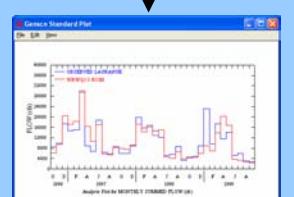
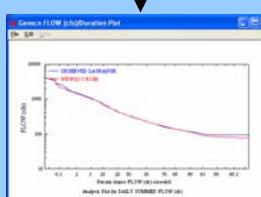
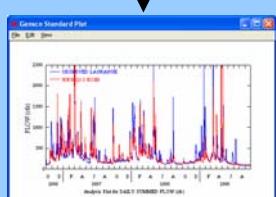
3. Monthly Flow Volumes

EXAMPLE APPLICATION Upper Wolf River, TN

WinHSPF Results
Default Parameters



WinHSPF Results
Optimized Parameters



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